Case report



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# *Special aspects of surgical tactics in treatment of patients with lumbar degenerative spondylolisthesis*

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**Purpose** To assess osteoconductive properties of carbon fibre implants used in surgery of spine injuries and disorders. **Materials and methods** Two clinical cases from a multicentre prospective study on nanostructured carbon fibrous implants applied for a variety of spinal pathology are presented. **Results** The usage of highly porous carbon fibre implant resulted in bone and carbon fusion in the clinical instances whereas implants with a residual porosity of 7–12 % showed no fusion between bone and carbon. The patients had satisfactory clinical condition and quality of life. **Discussion** Carbon fibrous implant characteristics are close to those of bone tissue, being inert and osteoconductive along with high mechanical strength that ensure bone and carbon fibrous fusion with highly porous implant.
**Keywords**: carbon fibre, nanostructured, implant, spondylodesis, graft, vertebral body replacement

## INTRODUCTION

Interactions of bone tissue and materials intended as part of implant used to stabilise vertebral columns play a critical role in surgical treatment of spinal injuries and disorders. Autologous bone is the current gold standard among the variety of biological and nonbiological materials used for spondylodesis. Although autogenous bone graft has many advantages complications such as resorption of autograft, nonunion, failure in donor site healing of the operated vertebral motion segment and the morbidity of the bone graft harvest procedure have been recorded. Limitations of the clinical use of allogeneic bone grafts include a complicated processing method of lyophilisation and desinfection; a risk of transmission of infection from donors to recipients, immune response to incorporation as well as ethical, cultural and religious concerns [1–5]. In our opinion, the use of nonbiological materials in spine surgery can be an alternative for a spinal fusion procedure to reduce surgical trauma, timing of surgery, pain relief in case of nonunion due to resorption of auto- or allograft and donor site morbidity. Carbon fibre offers many unique physical, chemical and biological characteristics that can be exploited for spinal fusion being Compared to titanium or PEEK implants carbon fibre is biologically inert having high affinity to bone tissue and elasticity. Carbon fibre technology is relatively low cost and carbon fibre can be material of choice with diamagnetic properties and pliability in intraoperative processing.

## MATERIAL AND METHODS

In 2015, we have initiated a multicentre prospective randomised study of carbon fibre implants in surgery of spinal injuries and disorders at the National Priorov Medical Research Centre of Traumatology and Orthopaedics of the RF Ministry of Health together with Novosibirsk Tsivyan Scientific Research Institute of Traumatology and Orthopaedics of the RF Ministry of Health and St. Petersburg Scientific Research Institute of Phthisiopulmonology of the RF Ministry of Health. The study included 136 patients with spinal injuries and disorders surgically treated with nanostructured carbon fibre implants (NCFI) and followed for 2 years. Surgical techniques employed with NCFI included spinal disc replacement, vertebral

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body replacement and interspinous stabilisation. Outcome measures included radiography, computed tomography (CT), magnetic resonance imaging (MRI), dual-energy X-ray absorptiometry (DEXA), visual analog scale (VAS), Amrican Spinal Injury Association (ASIA) Impairment Scale (for patients with spinal injuries), the Oswestry Disability Index (ODI) and the Short Form Health Survey (SF-36). The assessments were performed at 3, 6, 12 and 24 postoperative months.

## RESULTS

We report two clinical cases of vertebral body replacement with carbon fibre implants at 11/2-and-2-year prospective follow-up as a primary analysis of the findings obtained.

**Clinical case 1**. A 32-year-old male patient was seen at the hospital of the National Priorov Medical Research Centre of Traumatology and Orthopaedics and presented with pains in the thoracic spine and raised body temperature of 38° Celcius. He developed the condition due to a cold injury 2 weeks prior to his appointment. The patient was comprehensively examined and diagnosed with non-specific spondylitis of Th8–Th9 vertebral bodies and kyphosis. VAS score was 9 to 10; MH and HH scales of SF-36 measured 68 and 69, correspondingly, with ODI of 39 %. The patient underwent two-staged surgical treatment including transpedicular correction and fixation of the thoracic spine at the first phase and anterior necrsequestrectomy of Th8-Th9 vertebrae combined with high porous carbon fibre implantation (pore diameter of more than 1.5 mm) and autologous bone grafting (resected rib) to repair the defect (**Fig. 1**).

A 4-month follow-up showed early signs of bone healing between vertebral bodies and autograft, and osteosclerosis around carbon fibrous implant (**Fig. 2**). Bone graft and vertebral bodies was observed to fuse and bone-carbon fibrous block formed with pores filled with osseous tissue at 16-month follow-up (**Fig. 3**). VAS score was 0 to 1; MH and HH scales of SF-36 measured 81 and 90, correspondingly, with ODI of 10% that indicated to a good clinical and functional outcome of surgical treatment.

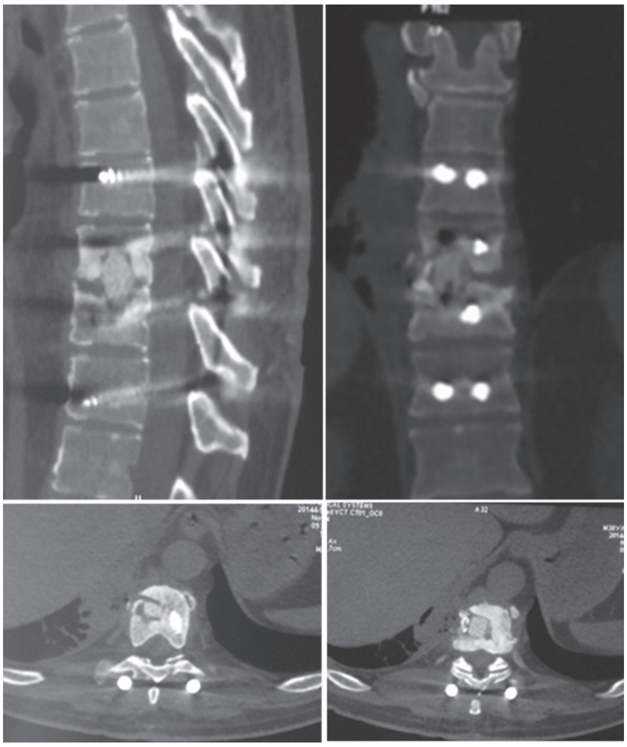


**Fig. 1** Clinical case 1 diagnosed with non-specific spondylitis of Th8–Th9 vertebral bodies showing transpedicular correction and fixation of the thoracic spine, anterior necrsequestrectomy of Th8–Th9 vertebrae followed by high porous carbon fibre implantation (pore diameter of more than 1.5 mm) and autologous bone grafting (resected rib) to repair the defect on the first day of two-staged surgical treatment

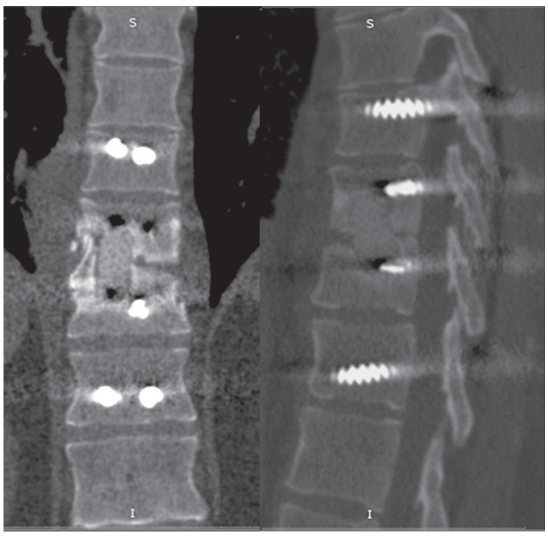
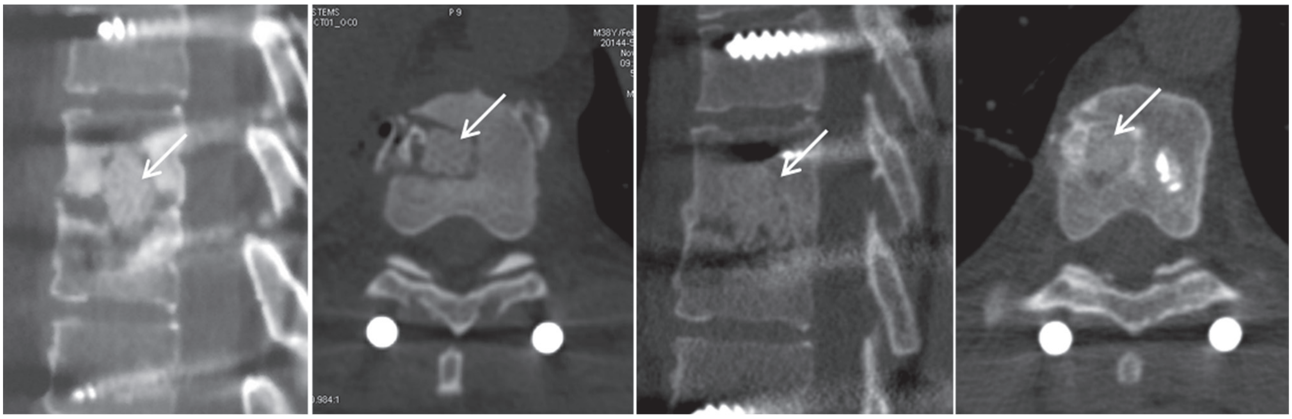



**Fig. 2** Clinical case 1: a 4-month follow-up showing early signs of bone healing between vertebral bodies and autograft and osteosclerosis around carbon fibre implant



a b c d

**Fig. 3** Clinical case 1: (a, b) the first postoperative day. Arrows showing pores of the implant; (c, d) a 16-month follow-up with bone and carbon fibrous block formed; arrows showing pores of the implant filled with osseous tissue

**Clinical case 2**. A 59-year-old male patient was seen at the spinal department of the National Priorov Medical Research Centre of Traumatology and Orthopaedics and presented with pains in the thoracic and lumbar spine, regular burning sensations at the buttocks, lateral and posterior femur and difficulties in urination. He sustained a straightforward injury to L1 vertebral body Denis type 1B due to a fall in November 2014. The first stage of surgical treatment included transpedicular fixation of Th12–L2 vertebrae and posterior spondylodesis performed next day of injury (**Fig. 4**). The patient was referred to the National Priorov Medical Research Centre of Traumatology and Orthopaedics for the second stage of surgical treatment including thoracophrenolumbotomy on the left, resection of L1 vertebral body, interbody combined corporodesis with carbon fibrous implant (residual porosity of 7 to 12 % and antograft (resected rib) in March 2015 (**Fig. 5**).

VAS score was 5 to 6; MH and HH scales of SF-36 measured 30 and 45, correspondingly, with ODI of 65% before the second stage of surgical treatment. A 6-month follow-up showed bone healing between vertebral bodies and autograft, osteosclerosis around carbon fibrous implant. Neither bone resorption around the screws of the metal construct nor migration, sagging of carbon fibrous implant developed at the time (**Fig. 6**). The carbon fibrous implant did not integrate at a 24-month follow-up, however, neither implant migration nor sagging were observed with autograft (resected rib) and vertebral bodies fused (**Fig.** 7). П VAS score was 0; MH and HH scales of SF-36 measured 75 and 80, correspondingly, with ODI of 5 % at 24 months of the second stage of surgical intervention.

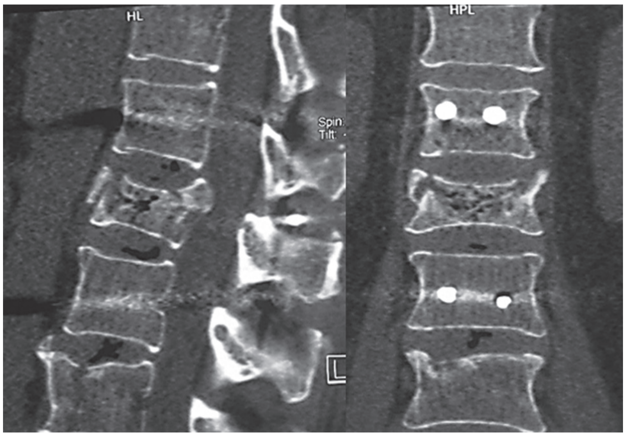


**Fig. 4** Clinical case 2: straightforward injury to L1 vertebral body Denis type 1B, condition after the first stage of surgical treatment including transpedicular fixation of Th12–L2 vertebrae and posterior spondylodesis

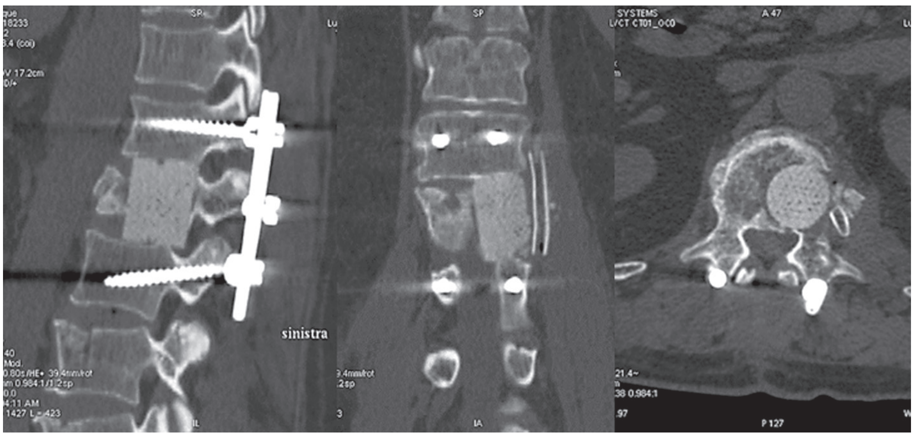



**Fig. 5** Clinical case 2: condition after the first stage of surgical treatment including resection of L1 vertebral body, combined interbody corporodesis with carbon fibrous implant and autograft

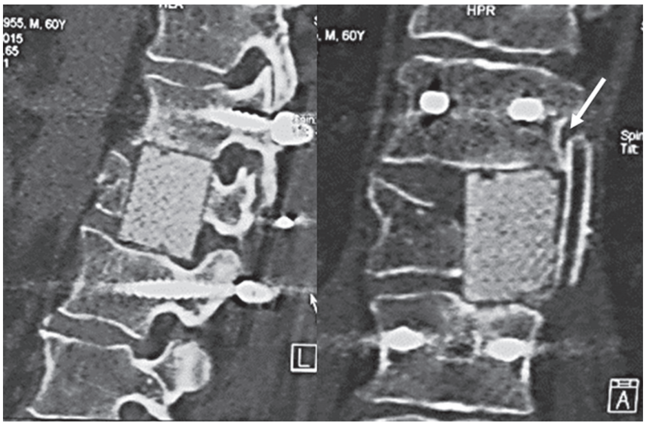


**Fig. 6** Clinical case 2: 6-month follow-up showing fusion of autograft and vertebral body with arrow

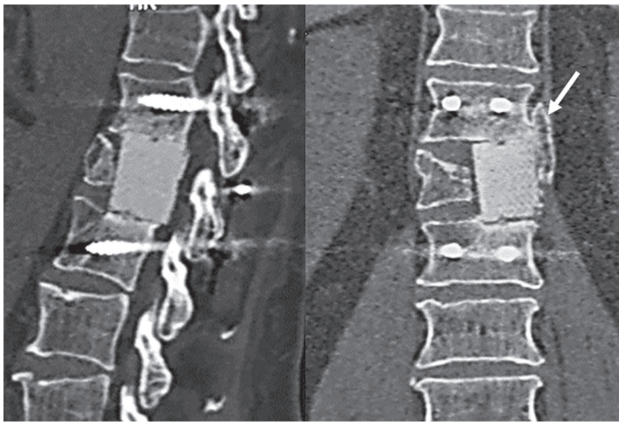


**Fig. 7** Clinical case 2: 24-month follow-up showing fusion of autograft and vertebral body with arrow

## DISCUSSION

Osteoconductivity is important for surgical spinal solutions in addition to mechanical properties of spinal implants and missing with the majority of artificial materials. They can have a role of foreign bodies with connective tissue sheath forming around the implants [6].

The paradigm of carbon fibre implants relies on the biological compatibility and biochemical composition being close to native bone that accounts for high superficial energy exceeding 0.05 J/m2 and greater positive potential. Contacts with bone tissue result in a thin poorly absorbing protein layer that serves as the origin for connective and bone tissue. Carbon is chemically inert and dissolves in organic and inorganic solvents and having no interactions with alkali, acid, salt, organic and biologically active entities. Carbon fibrous materials are resistant to corrosion to since they have greater electropositive potential [7–11]. In vivo laboratory studies of carbon containing implants showed histologically minimal tissue reaction, absence of osteoresorption and suppressed reparative regeneration at long terms of implantation [11]. The clinical instances reconfirmed the above. Implants were stable during a long period of time with no signs of resorption observed. Bone and carbon fibrous fusion was noted in one case (clinical case 1) due to highly porous implant with pore diameter of more than 1.5 mm, and no osteoconduction was observed in the second clinical instance of carbon fibre implantation with residual porosity of 7 to 12 %.

## CONCLUSION

As reported in literature and shown in our findings carbon fibrous implant characteristics are close to those of bone tissue, being inert and osteoconductive along with high mechanical strength that ensure bone and carbon fibrous fusion with highly porous implant. The above clinical instances cannot be a definitive opinion about characteristics of the implants described but the application of the carbon fibrous implants requires further investigation of interactions between carbon fibres and the bone, the influence on clinical course of the disease and quality of life of patients operated on with the implants.

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